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(54) **METHOD AND CLEANING APPARATUS FOR REMOVAL OF SOX AND NOX FROM EXHAUST GAS**

VERFAHREN UND REINIGUNGSVORRICHTUNG ZUM ENTFERNEN VON SOX UND NOX AUS
ABGAS

PROCEDE ET APPAREIL DE NETTOYAGE POUR LE TRAITEMENT DES SOX ET NOX DES GAZ
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• **ØVREBØ, Dag**

N-3921 Porsgrunn (NO)

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(74) Representative: **Alfa Laval Attorneys**

Alfa Laval Corporate AB

Patent Department

P.O. Box 73

221 00 Lund (SE)

(73) Proprietor: **Alfa Laval Aalborg A/S**

9000 Aalborg (DK)

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(72) Inventors:

• **MENON, Mohan**

N-3929 Porsgrunn (NO)

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Description

[0001] The present invention relates to a method and an apparatus for cleaning the exhaust gas from an internal combustion engine.

[0002] More specifically, the present invention relates to the removal of SO_x , NO_x and particulate matter from an exhaust gas which typically originates from an internal combustion engine on a vessel or other types of mobile units with an internal combustion engine which runs on diesel or heavy oil with a high content of sulphur.

[0003] When diesel or heavy oil with a high content of sulphur, i.e. a content of sulphur which is higher than about 100 ppm, is combusted, SO_x , NO_x and soot/particulate matter will form. Due to stricter restrictions on emissions from vessels, SO_x , NO_x and particulate matter (particles and soot) will largely have to be removed from the exhaust gas before the exhaust gas is released into the air.

[0004] A well known method for removal of SO_x from exhaust gas is by using a scrubber in which SO_x is removed by using water. The problem with scrubbers is that they are large structures, and use a substantial amount of power. The end product when removing SO_x with water is a sludge, which is a hazardous waste product that must be stored and deposited for further treatment. Because scrubbers are large structures, they also require a lot of space and substantial rebuilding if it is to be retrofitted on a vessel or other types of mobile units.

[0005] EP1612379 discloses an exhaust gas system including an exhaust drying unit and an exhaust cleaning unit. The cleaning unit may comprise a catalyst and/or a particle filter.

[0006] US6,240,725 discloses an apparatus and method for removal of particulate, nitrous oxide and sulfur oxides from exhaust from diesel internal combustion engines. The apparatus comprises a catalytic converter and a particle filter. The apparatus also comprises a heat exchanger for condensation of water that combines with oxides of nitrogen and sulfur.

[0007] In AU 2007219270 there is disclosed a method for production of highly concentrated and pure sulphuric acid wherein a sulphur source is combusted in a combustion chamber, SO_2 in the effluent is catalytically oxidized to SO_3 and the SO_3 is hydrated with water to sulphuric acid. The sulphuric acid is then condensed in order to separate the sulphuric acid from the effluent. The separation of the sulphuric acid is done by cooling the gas containing SO_3 to just below the acid dew point for sulphuric acid. Sulphuric acid is deposited on the surface of the pipes inside the condenser and is collected and cooled. Typical temperatures in this process are as follows:

[0008] The temperature of exhaust gases leaving the condenser is above 100°C , and the temperature of the sulphuric acid produced is just below the acid dew point (at least 125°C and usually higher, depending on the sulphur content). Handling and cooling of sulphuric acid

which is concentrated and hot, as in this process, requires special equipment. In addition, this process requires a substantial amount of energy and the installation itself is space-requiring.

[0009] As space and energy is of great importance in mobile use of IC-engines the method disclosed in the Australian publication is therefore presently not used in the maritime industry. In addition, handling of the corrosive condensate would be a problem on vessels and other mobile uses of IC-engines.

[0010] The objective of the present invention is thus to provide a process and an apparatus for removal of SO_2 , NO_x and particles and soot from an exhaust gas from an internal combustion engine which will remedy the problems mentioned above.

[0011] It is further an object of the present invention to obtain a process and an apparatus for removal of SO_2 , NO_x and particles and soot from an exhaust gas from an internal combustion engine where the process is more energy efficient than known processes.

[0012] It is further an object of the present invention to obtain a process and an apparatus for removal of SO_2 , NO_x and particles and soot from an exhaust gas from an internal combustion engine where the final products of the process can be stored on the vessel/vehicle and which has at least some value on the market.

[0013] It is further an object of the present invention to provide an apparatus for removal of SO_2 , NO_x and particles and soot from an exhaust gas from an internal combustion engine which is compact and is easy to retrofit on existing vessels and vehicles.

[0014] A further objective is to provide a process and an apparatus that avoids the formation of sludge.

[0015] These objectives are achieved with the claimed method as defined in claim 1 and the claimed cleaning apparatus as defined in claim 9, as well as the independent claims 16, 17 and 18. Further embodiments of the claimed invention are defined in the dependent claims.

[0016] The claimed invention is able to remove particles, soot and sulphur and to reduce NO_x from emissions of internal combustion engines (IC-engines). In the process particles may be removed, SO_2 is oxidized to SO_3 and NO is oxidized to NO_2 in a catalytic reactor. SO_3 and NO_2 react with water to form sulphuric and nitric acid, respectively. Thereafter sulphuric acid and nitric acid is condensed out of the exhaust gas at a condenser by cooling the exhaust gas below the dew point of the water in the exhaust gas. Thus both sulphur and NO_x are removed using water available in the exhaust in one step. A further advantage is that formation of acid mist is avoided by cooling below the dew point of the water in the exhaust gas.

[0017] In the claimed invention, typical temperatures are as follows:

[0018] Temperature of exhaust gas leaving the condenser will be below the dew point (the dew point temperature of the exhaust depends on the quality of the fuel and the load on the engine, but is always below 70°C) of

the water in the exhaust gas, preferably in the range 20°C-70°C, more preferably in the range 20°-50°C. The temperature of the condensed acid will always be lower than 70°C. The condensate is a mixture of sulphuric acid and nitric acid.

[0019] Due to the low operating temperatures, the apparatus for carrying out the process does not take much space and requires much less energy during operation as compared to the known processes described above.

[0020] The purity of the condensate is not of any big importance for the claimed invention. The main aim is to remove sulphur and other pollutants from the exhaust gas and to obtain a waste product that has some market value instead of having to be treated as hazardous matter which must be disposed (as for scrubber sludge). Such disposal of hazardous matter has a cost associated with it. The mixture of sulphuric acid and nitric acid mentioned above will still have some market value.

[0021] The claimed invention also comprises one or more particle filters for removal of particles and soot from the exhaust gas coming from an IC-engine. The particle filter or filters are placed before the catalytic reactor such that contamination of the catalyst is avoided.

[0022] In one aspect the present invention provides a cleaning apparatus wherein one or more particle filters for removal of particles and soot from the exhaust gas coming from an IC-engine are placed upstream a condenser and or scrubber such that contamination of the liquid within the condenser and or scrubber with particulate matter is avoided.

[0023] After being used for some time, the particle filter or filters will get blocked and will need to be regenerated. This is usually done by increasing the temperature of the exhaust gas to above 800°C under oxidizing conditions and thereby burning away the carbon deposits.

[0024] The claimed invention, however, regenerates the particle filter or filters by using cold flame gas also called cool flame gas which is passed through the particle filters when they need to be regenerated. The cold flame gas may also be used to heat the catalyst of the catalytic reactor before the catalyst reaches its operating temperature. Cold flame gas is produced in a cold flame generator in which a cold flame is maintained. In a cold flame the fuel is partially oxidized in preheated air. The temperature is kept constant below 550°C, and it is independent of air/fuel ratio and residence time. In the cold flame process, only a fraction of the calorific value of the fuel is released, often less than 50%, more often less than 40%, even more often 2-30% or even 2-20%. This heat is used to evaporate the remaining fuel, giving a homogenous gaseous fuel comprising the products of the partial oxidation and the remaining, evaporated fuel. Details and complete description of how to produce the cold flame gas can be found in the US patent US 6,793,693. Method for regeneration of particle filter or filters by using cold flame gas can be found in the applicant's patent, EP 2,198,133 B.

[0025] The term "cold flame" as used herein specifi-

cally refers to the cool flame phenomenon as described in the paragraph above. This phenomenon is well known to a person skilled in the art, and the name given to it refers to the relative low temperature of this specific flame compared to traditional flames and auto ignition temperatures of fuels. The cold flame can only be obtained and these low temperatures, at high temperatures the fuels will auto ignite and a normal combustion of the fuel will take place.

[0026] The "cold flame gas" comprises vaporised fuel, partially oxidized fuel including free radicals and unreacted oxygen or air. Accordingly the "cold flame gas" is a gas from a partial oxidation process which is not controlled or limited by either the full combustion of the fuel or the full combustion of the oxygen, as both unreacted oxygen and unreacted vaporised fuel form part of the cold flame gas.

[0027] The claimed invention provides a method and an apparatus that is able to remove sulphur and NO_x from the exhaust gas. Furthermore, in an embodiment, the claimed invention can remove all three pollutants, particulate matter, sulphur and NO_x from the exhaust gas. Since the purity of the sulphuric acid is not important, the condenser does not need to be operated at high temperatures. Because of this, less energy and less space, and no special equipment for handling hot and concentrated sulphuric acid, is needed. Furthermore, with the claimed method and apparatus exhaust gas from an IC-engine using fuel with high content of sulphur is cleaned without producing any waste that needs disposal.

[0028] Thus, there is disclosed a method for removal of SO_x and NO_x from an exhaust gas comprising SO_x, NO_x, soot and water, the exhaust gas originating from a combustion of a fuel where the combustion takes place in an internal combustion engine. The exhaust gas is passed through at least one catalytic reactor comprising an oxidation catalyst, in which catalytic reactor at least SO₂ is converted to SO₃ and NO is converted to NO₂. Thereafter the exhaust gas is passed through a condenser and cooled to a temperature which is below the dew point temperature of the water in the condenser such that SO₃, NO₂ and water is condensed and SO₃ and NO₂ is dissolved into the condensed water and removed from the exhaust gas.

[0029] The exhaust gas may be passed through a particle filter for removal of particulate matter before the exhaust gas is passed through the at least one catalytic reactor.

[0030] In the invention, at least some exhaust gas, is taken out downstream the catalytic reactor and upstream the condenser, and fed back into the exhaust gas upstream the at least one particle filter. NO₂ in the exhaust gas will then react with particulate matter in the particle filter and form N₂.

[0031] In an embodiment of the invention, at least some exhaust gas, taken out downstream the catalytic reactor and upstream the condenser, may be fed back into the internal combustion engine.

[0032] In another embodiment of the invention, the particle filter may be regenerated by passing a cold flame gas through the particle filter.

[0033] In another embodiment of the invention, the catalyst in the at least one catalytic reactor may be heated during up-start of the catalytic reactor by passing a cold flame gas or hot air, preferably from the cold flame generator, through the catalytic reactor.

[0034] In another embodiment of the invention, the exhaust gas is preferably cooled down to a temperature in the range 20°C-70°C, more preferably in the range 30°C-50°C, in the condenser.

[0035] In another aspect the method according to the present invention additional water is injected into the condenser. This additional water may provide cooling of the exhaust gas. The additional water may also dissolve SO₃ and NO₂ from the exhaust gas.

[0036] When the additional water is brought in contact with the exhaust in the form of water droplets these water droplets can capture and wash out acid mist droplets formed in the cooled exhaust. In a further aspect of the invention the method comprises recycling at least part of the additional water and condensed water and acids retrieved from the condenser to the condenser as the additional water.

[0037] In a further aspect the additional water may be seawater. Dissolved salts present in the seawater will react with the sulphuric acid and form sulphates. The obtained condensate stream comprising condensed water, additional water and sulphates may be disposed to the sea, as sulphates are normal components of seawater and particles in the exhaust gas have been removed upstream in the particle filter.

[0038] There is also disclosed a cleaning apparatus for removal of SO_x and NO_x from an exhaust gas comprising SO_x, NO_x, soot and water. The exhaust gas originates from combustion of a fuel which takes place in an internal combustion engine. The cleaning apparatus comprises at least one catalytic reactor which is fluidly connected to the internal combustion engine. The catalytic reactor comprises an oxidizing catalyst which at least converts SO₂ to SO₃ and NO to NO₂ when the exhaust gas is passed through the catalytic reactor. The apparatus further comprises a condenser which is fluidly connected to the catalytic reactor downstream the catalytic reactor. In the condenser the exhaust gas is cooled to a temperature which is below the dew point temperature of the water in the condenser such that the SO₃, the NO₂ and the water is condensed and the SO₃ and the NO₂ is dissolved into the condensed water and removed from the exhaust gas, whereby SO_x and NO_x is removed from the exhaust gas.

[0039] The cleaning apparatus further comprises a particle filter for removal of particulate matter in the exhaust gas before the exhaust gas flows through the at least one catalytic reactor. The particle filter is fluidly connected to the internal combustion engine and the catalytic reactor.

[0040] The cleaning apparatus comprises a conduit for transferring at least some exhaust gas from downstream the catalytic reactor and upstream the condenser, back into the exhaust gas upstream the particle filter.

[0041] The term "conduit" as used here refers a pipeline, channel, flow path or any other means for providing fluid communication including any means for flowing.

[0042] In another embodiment of the cleaning apparatus the cleaning apparatus may comprise a conduit for transferring at least some exhaust gas from downstream the particle filter and upstream the catalytic reactor, back into the internal combustion engine in an EGR-loop.

[0043] In another embodiment of the cleaning apparatus the cleaning apparatus may further comprise a cold flame generator in which a cold flame gas is produced. The cold flame generator is preferably fluidly connected to the particle filter such that the cold flame gas can flow through the particle filter.

[0044] In another embodiment of the cleaning apparatus the cleaning apparatus may further comprise a cold flame generator in which a cold flame gas is produced, the cold flame generator being fluidly connected to the catalytic reactor such that the cold flame gas or hot air can flow through the catalytic reactor. The cold flame generator comprises a hot air inlet and a fuel inlet. The hot air and the fuel are reacted in the cold flame generator to provide cold flame gas. If no fuel is added the hot air can flow unreacted into the catalytic reactor. This feature may effectively be used to heat the catalytic reactor in a start up situation, for instance prior to starting the engine.

[0045] In another embodiment of the cleaning apparatus, the exhaust gas is preferably cooled down to a temperature in the range 20°C-70°C, more preferably in the range 30°C-50°C, in the condenser.

[0046] A vessel is also provided, which comprises an internal combustion engine and a cleaning apparatus as described above for removing SO_x, NO_x and soot from an exhaust gas wherein the cleaning apparatus is fluidly connected to the internal combustion engine such that exhaust gas from the internal combustion engine can flow through the cleaning apparatus. As used here the term "vessel" refers to a transport vessel such as a boat or a ship.

[0047] The term "particulate matter" as used here refers to soot and other particles present in an exhaust gas from an internal combustion engine.

[0048] The present invention further provides a method for removal of particulate matter and SO_x from an exhaust gas comprising SO_x and particulate matter, the exhaust gas originating from a combustion of a fuel where the combustion takes place in an internal combustion engine, wherein the exhaust gas is passed through a particle filter for removal of particulate matter before the exhaust gas is passed through at least one catalytic reactor for removal of SO_x in which catalytic reactor at least SO₂ is converted to SO₃ and where after the exhaust gas is passed through a scrubber and cooled by contact with a scrubbing liquid to a temperature such that SO₃ is con-

densed and SO_3 is dissolved into the scrubbing liquid, wherein the method comprises regeneration of the particle filter by the use of cold flame gas. This aspect of the present invention avoids the formation of sludge in the scrubber as particulate matter otherwise resulting in the formation of sludge is removed upstream the scrubber.

[0049] In a further aspect of this method removal of NO_x is also included in that the at least one catalytic reactor comprises an oxidation catalyst, in which catalytic reactor at least SO_2 is converted to SO_3 and NO is converted to NO_2 .

[0050] The present invention also provides a cleaning apparatus for removal of particulate matter and SO_x from an exhaust gas comprising SO_x and particulate matter, the exhaust gas originating from a combustion of a fuel where the combustion takes place in an internal combustion engine, the apparatus comprising at least one catalytic reactor which is fluidly connected to the internal combustion engine, the catalytic reactor comprising an oxidizing catalyst which at least converts SO_2 to SO_3 when the exhaust gas is passed through the catalytic reactor, where the apparatus comprises a particle filter for removal of particulate matter in the exhaust gas before the exhaust gas flows through the at least one catalytic reactor, the particle filter being fluidly connected to the internal combustion engine and the catalytic reactor, the apparatus further comprising a scrubber which is fluidly connected to the catalytic reactor downstream the catalytic reactor, in which scrubber the exhaust gas is cooled by contact with a scrubbing liquid to a temperature such that the SO_3 is condensed and the SO_3 is dissolved into the scrubbing liquid and thereby removed from the exhaust gas, wherein the apparatus comprises a cold flame generator in which a cold flame gas is produced, the cold flame generator being fluidly connected to the particle filter such that the cold flame gas can flow through the particle filter, such that the filter is regenerated. This aspect of the present invention avoids the formation of sludge in the scrubber as particulate matter otherwise resulting in the formation of sludge is removed in the particle filter upstream the scrubber.

In a further aspect this apparatus, may further comprise the cold flame generator being fluidly connected to the catalytic reactor such that the cold flame gas can flow through the catalytic reactor. In this aspect both the particle filter and the catalytic reactor are regenerated by the cold flame gas.

In the following, several non-limiting embodiments of the claimed invention will be described in detail, with reference to the figures, where

Figure 1 schematically illustrates an example not representative of the invention.

Figure 2 schematically illustrates an embodiment of the present invention wherein exhaust gas is returned from downstream the oxidation catalytic reactor to the exhaust gas upstream the particle filter.

Figure 3 schematically illustrates an embodiment of the present invention which is similar to the embodiment in Figure 2, but where there are two parallel flow paths.

Figure 4 schematically illustrates an other example not representative of the invention wherein exhaust gas is returned from downstream the particle filter to the internal combustion engine.

In all Figures 1-4 the same technical features are given the same reference numbers. It should also be noted that the figures show the main parts of the present invention while other standard parts such as valve devices have not all been included. Such devices would, however, be obvious for a person skilled in the art to include in the cleaning apparatus where and when that is necessary. In figure 1 there is shown an example, not representative of the invention, of a cleaning apparatus 10 for removing SO_x , NO_x and soot/particulate matter from an exhaust gas. The exhaust gas is produced in an IC-engine 12, typically an IC-engine on a vessel, but may also be an IC-engine arranged on other types of equipment such as vehicles, electrical generators driven by an IC-engine and so on.

Fuel is fed into the IC-engine 12 through a fluid flow path 13. Air is fed into the IC-engine through a fluid flow path 14. In the combustion chamber of the IC-engine (not shown in the figures) the fuel is combusted with the air and forms an exhaust gas. The fuel comprises a high content of sulphur which forms predominantly SO_2 during the combustion process in the IC-engine. Due to restrictions on emissions in exhaust gas, SO_2 must be removed from the exhaust gas, at least so much of it that the sulphur content in the exhaust gas released into the atmosphere is below the limits set by official standards and requirements. For example for marine vessel the limits for SO_x and NO_x in the exhaust gas is given in the IMO regulations (IMO = International Maritime Organization).

[0051] The cleaning apparatus is connected to the IC-engine 12 with a fluid flow path 25 which fluidly connects a particle filter 16 to the IC-engine.

Downstream the particle filter 16 a catalytic reactor 18 is arranged in fluid communication with the particle filter through a fluid flow path 26. The catalytic reactor 18 comprises at least one oxidizing catalyst such that SO_x , typically SO_2 , is converted to SO_3 and such that NO_x , typically NO , is converted to NO_2 . The oxidizing catalyst may for example be a vanadium pentoxide catalyst or another suitable catalyst. The particle filter 16 removes soot and particles which are present in the exhaust gas and which may damage or reduce the efficiency of the oxidizing catalyst in the catalytic reactor 18.

The cleaning apparatus 10 further comprises a condenser 20 which is fluidly connected to the catalytic reactor 18 downstream the catalytic reactor with a fluid flow path 27. The condenser 20 cools the exhaust gas below the dew point temperature of the water contained in the con-

denser 20, i.e. the exhaust gas is cooled down to a temperature in the range 20°C-70°C, or more preferably, in the range 20°C-50°C. The water will be part of the exhaust gas as a result of the combustion process in the IC-engine. The cleaning apparatus 10 may, however, be provided with a fluid flow path 21 connected to a source of water such that water can be injected into the condenser 20 if necessary. A valve device 22 controls the flow of water through the fluid flow path 21.

When the exhaust gas is cooled below the dew point temperature of the water, the water is condensed, the SO₃ in the exhaust gas is also condensed out such that sulphuric acid is formed and the NO₂ in the exhaust gas is condensed out such that nitric acid is formed. A fluid flow path 23 is connected to a first outlet of the condenser 20 through which the mixture of sulphuric acid, nitric acid and water leaves the condenser. A fluid flow path 28 is connected to a second outlet of the condenser 20 through which the remaining exhaust gas leaves the condenser 20. The cleaning apparatus 10 shown in Figure 1 is also provided with a cold flame generator 30 in which a cold flame gas is produced. Fuel is fed into the cold flame generator through a fluid flow path 31 while preheated air is fed into the cold flame generator through a fluid flow path 32. The fuel may be the same fuel that is fed into the IC-engine 10. In the cold flame generator, the fuel is partially oxidized to form a cold flame gas as explained above. A fluid flow path 33 is connected to the cold flame generator 30 and the fluid flow path 25 such that the cold flame gas produced in the cold flame generator 30 may flow from the cold flame generator 30 into the fluid flow path 25. The fluid flow path 33 is provided with a valve device 34 such that the flow of cold flame gas through the fluid flow path 33 may be controlled. The cold flame gas is used to regenerate the particle filter 16 when it has become partly or completely blocked by soot/particulate matter. To regenerate the particle filter 16 cold flame gas is transferred from the cold flame generator and through the particle filter 16. The cold flame gas will oxidize the soot and thereby regenerate the particle filter 16. The cold flame gas may also be used to heat up the oxidizing catalyst in the catalytic reactor 18 to its working temperature, which is between 300°C-700°C, before exhaust gas from the IC-engine is passed through the catalytic reactor. The resulting exhaust gas, after having been past through the cleaning apparatus 10, has a very low content of sulphur and soot/particulate matter.

The embodiment of the present invention shown in Figure 2 is very similar to the example shown in Figure 1. As mentioned above, the same technical features have the same reference numbers in all figures and will therefore not be repeated again.

[0052] The embodiment in Figure 2 differs from the example shown in Figure 1 in that the cleaning apparatus 10 further is provided with a fluid flow line 36 which in one end is connected to the fluid flow path 27, which fluidly connects the catalytic reactor 18 and the condenser 20, and to the fluid flow path 25, which fluidly connects

the particle filter 16 and the IC-engine when the cleaning apparatus is operating. The fluid flow path 36 is preferably provided with a valve device 37 such that the flow of exhaust gas through the fluid flow path 36 may be controlled. The inclusion of the fluid flow path 36 means that exhaust gas downstream the catalytic reactor 18, which comprises NO₂, can be returned to the exhaust gas upstream the particle filter 16. When the NO₂ flows through the particle filter 16 soot will react with the NO₂ and form N₂ which contributes to reducing the content of NO_x in the exhaust gas and at the same time removes soot from the particle filter 16.

[0053] With this embodiment of the present invention, the resulting exhaust gas, after having been past through the cleaning apparatus 10, has a very low content of sulphur and soot and a low content of NO_x.

The embodiment shown in Figure 3 is similar to the embodiment shown in Figure 2. The difference is that the cleaning apparatus 10 is provided with two particle filters 16a, 16b and two catalytic reactors 18a, 18b where the particle filter 16a and the catalytic reactor 18a is arranged in a first branch of two parallel fluid flow paths for the exhaust gas, while the particle filter 16b and the catalytic reactor 18b is provided in the second branch of the two parallel fluid flow paths.

[0054] The fluid flow path 25 which is fluidly connected to the IC-engine when the cleaning apparatus 10 is operating, is divided into two branches at a first fluid flow path connection 24, a first branch 44 and a second branch 45. The two branches 44, 45 are joined together again in a second fluid flow path connection 29 as shown in Figure 3.

[0055] The first branch 44 comprises a particle filter 16a which is fluidly connected to the fluid flow path connection 24 with a fluid flow path 25a. The particle filter 16a is fluidly connected to a catalytic reactor 18a which is arranged downstream the particle filter 16a. The catalytic reactor 18a is further fluidly connected to the second fluid flow path connection 29 which is downstream the catalytic reactor 18a, with a fluid flow path 27a. Similar to the embodiment shown in Figure 2, there is also provided a fluid flow path 36a which is connected in one end to the fluid flow path 27a and in the other end to the fluid flow line 25a such that exhaust gas flowing in the fluid flow path 27a downstream the catalytic reactor 18a can be returned and fed into the exhaust gas flowing in the fluid flow path 25a. The fluid flow path 36a is preferably provided with a valve device 37a such that the flow of exhaust gas through the fluid flow path 36a can be controlled.

[0056] The second branch 45 comprises a particle filter 16b which is fluidly connected to the fluid flow path connection 24 with a fluid flow path 25b. The particle filter 16b is fluidly connected to a catalytic reactor 18b which is arranged downstream the particle filter 16b. The catalytic reactor 18b is further fluidly connected to the second fluid flow path connection 29 which is downstream the catalytic reactor 18b, with a fluid flow path 27b. Similar

to the embodiment shown in Figure 2, there is also provided a fluid flow path 36b which is connected in one end to the fluid flow path 27b and in the other end to the fluid flow line 25b such that exhaust gas flowing in the fluid flow path 27b downstream the catalytic reactor 18b can be returned and fed into the exhaust gas flowing in the fluid flow path 25b. The fluid flow path 36b is preferably provided with a valve device 37b such that the flow of exhaust gas through the fluid flow path 36b can be controlled.

[0057] An alternative for routing the fluid flow paths 36a, 36b is to connect one end of the fluid flow path 36a to the fluid path 27a and the other end of the fluid flow path 36a to the fluid flow path 25b such that exhaust gas can be flowed from downstream the catalytic reactor 18a to upstream the particle filter 16b. Similarly, one end of the fluid flow path 36b can be connected to the fluid path 27b while the other end of the fluid flow path 36b is connected to the fluid flow path 25a such that exhaust gas can be flowed from downstream the catalytic reactor 18b to upstream the particle filter 16a.

[0058] With this embodiment of the present invention, the resulting exhaust gas, after having been past through the cleaning apparatus 10, has a very low content of sulphur, NO_x and soot.

[0059] In Figure 4 there is shown an other example not representative of the invention and similar to the example of Figure 1. The only difference between the examples in Figure 4 and in Figure 1 is that the example in Figure 4 is provided with an EGR-loop (exhaust gas recirculation). The cleaning apparatus 10 is provided with a fluid flow path 39 which in one end is connected to the fluid flow path 26, which connects the particle filter 16 and the catalytic reactor 18, and in the other end is connected to the engine 10 when the cleaning apparatus is operating such that exhaust gas can be past from the fluid flow path 26 back to the combustion chamber in the IC-engine 10. The fluid flow path 39 may be provided with a cooler 40 such that the exhaust gas may be cooled before being returned back into the combustion chamber and a valve device 41 such that the flow of exhaust gas through the fluid flow path 39 can be controlled. When the exhaust gas is returned back into the combustion chamber, the result is that the content of NO_x in the exhaust gas is lowered.

[0060] With this example, the resulting exhaust gas after having been past through the cleaning apparatus 10, has a very low content of sulphur and soot and a low content of NO_x.

The fluid flow paths 13, 14, 21, 23, 25, 26, 26a, 26b, 27, 27a, 27b, 28, 31, 32, 31, 33, 33a, 33b, 36, 36a, 36b, 39 are typically fluid lines in the form of pipes, tubes, conduits or similar devices through which a fluid can flow.

As can be seen from the description of the various embodiments of the present invention, after the exhaust gas has been passed through the cleaning apparatus 10, a substantial amount of SO_x, NO_x and soot/particulate matter have been removed from the exhaust gas originating

from the combustion process in the IC-engine 10. The content of SO_x and NO_x is well below the requirement in the IMO regulations, and generally the exhaust gas is very clean.

Claims

1. A method for removal of SO_x and NO_x from an exhaust gas comprising SO_x, NO_x, soot and water vapour, the exhaust gas originating from a combustion of a fuel where the combustion takes place in an internal combustion engine (12), wherein the exhaust gas is passed through at least one catalytic reactor (18) comprising an oxidation catalyst, in which catalytic reactor (18) at least SO₂ is converted to SO₃ and NO is converted to NO₂, where after the exhaust gas is passed through a condenser (20) and cooled to a temperature which is below the dew point temperature of the water in the condenser such that SO₃, NO₂ and water is condensed and SO₃ and NO₂ is dissolved into the condensed water and removed from the exhaust gas, wherein the exhaust gas is passed through a particle filter (16) for removal of particulate matter before the exhaust gas is passed through the at least one catalytic reactor (18), **characterised in that** at least some exhaust gas, taken out downstream the catalytic reactor (18) and upstream the condenser (20), is fed back into the exhaust gas upstream the at least one particle filter (16).
2. Method according to claim 1, wherein at least some exhaust gas, taken out downstream the particle filter (16) and upstream the catalytic reactor (18), is fed back into the internal combustion engine (12).
3. Method according to one of the claims 1-2, wherein the particle filter (16) is regenerated by passing a cold flame gas through the particle filter.
4. Method according to one of the claims 1-3, wherein the catalyst in the at least one catalytic reactor (18) is heated during up-start of the catalytic reactor by passing a cold flame gas through the catalytic reactor.
5. Method according to one of the claims 1-4, wherein exhaust gas is cooled down to a temperature in the range 20°C-70°C, more preferably in the range 30°C-50°C.
6. Method according to one of the claims 1-5, wherein water is injected into the condenser (20).
7. A cleaning apparatus (10) for removal of SO_x and

NO_x from an exhaust gas comprising SO_x, NO_x, soot and water vapor, the exhaust gas originating from a combustion of a fuel where the combustion takes place in an internal combustion engine (12), the apparatus comprising at least one catalytic reactor (18) which is fluidly connected to the internal combustion engine (12), the catalytic reactor (18) comprising an oxidizing catalyst which at least converts SO₂ to SO₃ and NO to NO₂ when the exhaust gas is passed through the catalytic reactor (18), wherein the apparatus (10) comprises a particle filter (16) for removal of particulate matter in the exhaust gas before the exhaust gas flows through the at least one catalytic reactor (18), the particle filter (16) being fluidly connected to the internal combustion engine (12) and the catalytic reactor (18), the apparatus (10) further comprising a condenser (20) which is fluidly connected to the catalytic reactor (18) downstream the catalytic reactor (18), in which condenser (20) the exhaust gas is cooled to a temperature which is below the dew point temperature of the water in the condenser (20) such that the SO₃, the NO₂ and the water is condensed and the SO₃ and the NO₂ is dissolved into the condensed water and removed from the exhaust gas whereby SO_x and NO_x is removed from the exhaust gas,

characterised in that

the apparatus comprises a conduit (36) for transferring at least some exhaust gas from downstream the catalytic reactor (18) and upstream the condenser (20), back into the exhaust gas upstream the particle filter (16).

8. A cleaning apparatus according to claim 7, wherein the apparatus comprises a conduit (39) for transferring at least some exhaust gas from downstream the particle filter (16) and upstream the catalytic reactor (18), back into the internal combustion engine (12) in an EGR-loop.
9. A cleaning apparatus according to one of the claims 7-8, wherein the apparatus further comprises a cold flame generator (30) in which a cold flame gas is produced, the cold flame generator being fluidly connected to the particle filter (16) such that the cold flame gas can flow through the particle filter.
10. A cleaning apparatus according to one of the claims 7-9, wherein the apparatus further comprises a cold flame generator (30) in which a cold flame gas is produced, the cold flame generator being fluidly connected to the catalytic reactor (18) such that the cold flame gas can flow through the catalytic reactor.
11. A cleaning apparatus according to one of the claims 7-10,

wherein the condenser (20) is connected to a fluid flow path which is connected to a source of water such that water can be injected into the condenser.

12. A vessel comprising an internal combustion engine (12) and a cleaning apparatus (10) for removing SO_x, NO_x and soot from an exhaust gas according one of the claims 7-11 wherein the cleaning apparatus (10) is fluidly connected to the internal combustion engine (12) such that exhaust gas from the internal combustion engine can flow through the cleaning apparatus.

Patentansprüche

1. Verfahren zum Entfernen von SO_x und NO_x aus einem Abgas, beinhaltend SO_x, NO_x, Ruß und Wasserdampf, wobei das Abgas aus der Verbrennung eines Kraftstoffs stammt, wobei die Verbrennung in einem Verbrennungsmotor (12) erfolgt, wobei das Abgas durch mindestens einen katalytischen Reaktor (18) durchgeleitet wird, welcher einen Oxidations-Katalysator beinhaltet, wobei im katalytischen Reaktor (18) mindestens SO₂ in SO₃ und NO in NO₂ umgewandelt wird, wobei nach Durchleiten des Abgases durch einen Kondensator (20) und Abkühlen auf eine Temperatur, welche unter der Taupunkttemperatur des Wassers im Kondensator liegt in der Weise, dass SO₃, NO₂ und Wasser kondensiert und SO₃ und NO₂ im kondensierten Wasser aufgelöst und aus dem Abgas entfernt werden, wobei das Abgas durch einen Partikelfilter (16) zum Entfernen von partikelförmiger Materie durchgeleitet wird, bevor das Abgas durch den mindestens einen katalytischen Reaktor (18) durchgeleitet wird, **dadurch gekennzeichnet, dass** mindestens eine Menge an Abgas, welche im nachgelagerten Bereich des katalytischen Reaktors (18) und im vorgelagerten Bereich des Kondensators (20) entnommen wird, in das Abgas im vorgelagerten Bereich des mindestens einen Partikelfilters (16) zurückgespeist wird.
2. Verfahren nach Anspruch 1, bei welchem mindestens eine Menge an Abgas, welche im nachgelagerten Bereich des Partikelfilters (16) und im vorgelagerten Bereich des katalytischen Reaktors (18) entnommen wird, in den Verbrennungsmotor (12) zurückgespeist wird.
3. Verfahren nach einem der Ansprüche 1 bis 2, bei welchem der Partikelfilter (16) durch Durchleiten eines Gases mit kalter Flamme durch den Partikelfilter regeneriert wird.
4. Verfahren nach einem der Ansprüche 1 bis 3, bei welchem der Katalysator in dem mindestens ei-

nen katalytischen Reaktor (18) beim Hochstarten des katalytischen Reaktors durch das Durchleiten eines Gases mit kalter Flamme durch den katalytischen Reaktor erhitzt wird.

5. Verfahren nach einem der Ansprüche 1 bis 4, bei welchem Abgas auf eine Temperatur im Bereich zwischen 20°C und 70°C abgekühlt wird, noch bevorzugter Weise im Bereich zwischen 30°C und 50°C.
6. Verfahren nach einem der Ansprüche 1 bis 5, bei welchem Wasser in den Kondensator (20) injiziert wird.
7. Reinigungsapparat (10) zum Entfernen von SO_x und NO_x aus einem Abgas, beinhaltend SO_x, NO_x, Ruß und Wasserdampf, wobei das Abgas aus der Verbrennung eines Kraftstoffs stammt, wobei die Verbrennung in einem Verbrennungsmotor (12) erfolgt, wobei der Apparat mindestens einen katalytischen Reaktor (18) beinhaltet, welcher fluidisch mit dem Verbrennungsmotor (12) verbunden ist, wobei der katalytische Reaktor (18) einen Oxidations-Katalysator beinhaltet, welcher mindestens SO₂ in SO₃ und NO in NO₂ umwandelt, wenn das Abgas durch den katalytischen Reaktor (18) durchgeleitet wird, wobei der Apparat (10) einen Partikelfilter (16) zum Entfernen von partikelförmiger Materie im Abgas beinhaltet, bevor das Abgas durch den mindestens einen katalytischen Reaktor (18) hindurchströmt, wobei der Partikelfilter (16) fluidisch mit dem Verbrennungsmotor (12) und dem katalytischen Reaktor (18) verbunden ist, wobei der Apparat (10) zudem einen Kondensator (20) beinhaltet, welcher fluidisch mit dem katalytischen Reaktor (18) im nachgelagerten Bereich des katalytischen Reaktors (18) verbunden ist, wobei im Kondensator (20) das Abgas auf eine Temperatur abgekühlt wird, die unter der Taupunkttemperatur des Wassers im Kondensator (20) liegt in der Weise, dass das SO₃, das NO₂ und das Wasser kondensiert werden und das SO₃ und das NO₂ im kondensierten Wasser aufgelöst und aus dem Abgas entfernt werden, wobei SO_x und NO_x aus dem Abgas entfernt werden, **dadurch gekennzeichnet, dass** der Apparat eine Leitung (36) zum Transferieren von mindestens einer Menge des Abgases aus dem nachgelagerten Bereich des katalytischen Reaktors (18) und dem vorgelagerten Bereich des Kondensators (20) zurück in das Abgas im vorgelagerten Bereich des Partikelfilters (16) beinhaltet.
8. Reinigungsapparat nach Anspruch 7, bei welchem der Apparat eine Leitung (39) zum Transferieren von mindestens einer Menge des Abgases aus dem nachgelagerten Bereich des Partikelfilters (16) und dem vorgelagerten Bereich des

katalytischen Reaktors (18) zurück in den Verbrennungsmotor (16) in einer EGR-Schleife beinhaltet.

9. Reinigungsapparat nach einem der Ansprüche 7 bis 8, bei welchem der Apparat zudem einen Kaltflamengenerator (30) beinhaltet, in welchem ein Gas mit kalter Flamme produziert wird, wobei der Kaltflamengenerator fluidisch mit dem Partikelfilter (16) in der Weise verbunden ist, dass das Gas mit kalter Flamme durch den Partikelfilter strömen kann.
10. Reinigungsapparat nach einem der Ansprüche 7 bis 9, bei welchem der Apparat zudem einen Kaltflamengenerator (30) beinhaltet, in welchem ein Gas mit kalter Flamme produziert wird, wobei der Kaltflamengenerator fluidisch mit dem katalytischen Reaktor (18) in der Weise verbunden ist, dass das Gas mit kalter Flamme durch den katalytischen Reaktor strömen kann.
11. Reinigungsapparat nach einem der Ansprüche 7 bis 10, bei welchem der Kondensator (20) mit einem Fluidströmungsweg verbunden ist, welcher mit einer Wasserquelle in der Weise verbunden ist, dass Wasser in den Kondensator injiziert werden kann.
12. Wasserfahrzeug, beinhaltend einen Verbrennungsmotor (12) und einen Reinigungsapparat (10) zum Entfernen von SO_x, NO_x und Ruß aus einem Abgas nach einem der Ansprüche 7 bis 11, bei welchem der Reinigungsapparat (10) fluidisch mit dem Verbrennungsmotor (12) in der Weise verbunden ist, dass Abgas aus dem Verbrennungsmotor durch den Reinigungsapparat hindurch strömen kann.

Revendications

1. Procédé pour l'élimination des SO_x et des NO_x d'un gaz d'échappement comprenant des SO_x, des NO_x, de la suie et de la vapeur d'eau, le gaz d'échappement émanant d'une combustion d'un combustible où la combustion a lieu dans un moteur à combustion interne (12), dans lequel le gaz d'échappement est passé à travers au moins un réacteur catalytique (18) comprenant un catalyseur à oxydation, réacteur catalytique (18) dans lequel au moins le SO₂ est converti en SO₃ et le NO est converti en NO₂, où après que le gaz d'échappement est passé à travers un condenseur (20) et refroidi à une température qui est en dessous de la température de point de rosée de l'eau dans le condenseur de telle sorte que le SO₃, le NO₂ et l'eau sont condensés et le SO₃ et le NO₂ sont dissous dans l'eau condensée et éliminés du gaz d'échappement,

- dans lequel le gaz d'échappement est passé à travers un filtre à particules (16) pour l'élimination de matière particulaire avant que le gaz d'échappement soit passé à travers l'au moins un réacteur catalytique (18),
- caractérisé en ce qu'**au moins une partie du gaz d'échappement, prélevée en aval du réacteur catalytique (18) et en amont du condensateur (20), est réinjectée dans le gaz d'échappement en amont de l'au moins un filtre à particules (16).
2. Procédé selon la revendication 1, dans lequel au moins une partie du gaz d'échappement, prélevée en aval du filtre à particules (16) et en amont du réacteur catalytique (18), est réinjectée dans le moteur à combustion interne (12).
 3. Procédé selon l'une des revendications 1-2, dans lequel le filtre à particules (16) est régénéré en passant un gaz à flamme froide à travers le filtre à particules.
 4. Procédé selon l'une des revendications 1-3, dans lequel le catalyseur dans l'au moins un réacteur catalytique (18) est chauffé pendant un démarrage du réacteur catalytique en passant un gaz à flamme froide à travers le réacteur catalytique.
 5. Procédé selon l'une des revendications 1-4, dans lequel un gaz d'échappement est refroidi jusqu'à une température dans la plage de 20°C-70°C, plus préférentiellement dans la plage de 30°C-50°C.
 6. Procédé selon l'une des revendications 1-5, dans lequel de l'eau est injectée dans le condensateur (20).
 7. Appareil de nettoyage (10) pour l'élimination des SO_x et des NO_x d'un gaz d'échappement comprenant des SO_x , des NO_x , de la suie et de la vapeur d'eau, le gaz d'échappement émanant d'une combustion d'un combustible où la combustion a lieu dans un moteur à combustion interne (12), l'appareil comprenant au moins un réacteur catalytique (18) qui est raccordé de manière fluide au moteur à combustion interne (12), le réacteur catalytique (18) comprenant un catalyseur oxydant qui convertit au moins le SO_2 en SO_3 et le NO en NO_2 lorsque le gaz d'échappement est passé à travers le réacteur catalytique (18), dans lequel l'appareil (10) comprend un filtre à particules (16) pour l'élimination de matière particulaire dans le gaz d'échappement avant que le gaz d'échappement circule à travers l'au moins un réacteur catalytique (18), le filtre à particules (16) étant raccordé de manière fluide au moteur à combustion interne (12) et au réacteur catalytique (18), l'appareil (10) comprenant en outre un condensateur (20) qui est raccordé de manière fluide au réacteur catalytique (18) en aval du réacteur catalytique (18), condensateur (20) dans lequel le gaz d'échappement est refroidi à une température qui est en dessous de la température de point de rosée de l'eau dans le condensateur (20) de telle sorte que le SO_3 , le NO_2 et l'eau sont condensés et le SO_3 et le NO_2 sont dissous dans l'eau condensée et éliminés du gaz d'échappement, moyennant quoi les SO_x et les NO_x sont éliminés du gaz d'échappement, **caractérisé en ce que** l'appareil comprend une conduite (36) pour retransférer au moins une partie du gaz d'échappement de l'aval du réacteur catalytique (18) et de l'amont du condensateur (20) dans le gaz d'échappement en amont du filtre à particules (16).
 8. Appareil de nettoyage selon la revendication 7, dans lequel l'appareil comprend une conduite (39) pour retransférer au moins une partie du gaz d'échappement de l'aval du filtre à particules (16) et de l'amont du réacteur catalytique (18) dans le moteur à combustion interne (12) dans un circuit RGE.
 9. Appareil de nettoyage selon l'une des revendications 7-8, dans lequel l'appareil comprend en outre un générateur de flamme froide (30) dans lequel un gaz à flamme froide est produit, le générateur de flamme froide étant raccordé de manière fluide au filtre à particules (16) de telle sorte que le gaz à flamme froide peut circuler à travers le filtre à particules.
 10. Appareil de nettoyage selon l'une des revendications 7-9, dans lequel l'appareil comprend en outre un générateur de flamme froide (30) dans lequel un gaz à flamme froide est produit, le générateur de flamme froide étant raccordé de manière fluide au réacteur catalytique (18) de telle sorte que le gaz à flamme froide peut circuler à travers le réacteur catalytique.
 11. Appareil de nettoyage selon l'une des revendications 7-10, dans lequel le condensateur (20) est raccordé à un chemin de circulation de fluide qui est raccordé à une source d'eau de telle sorte que de l'eau peut être injectée dans le condensateur.
 12. Vaisseau comprenant un moteur à combustion interne (12) et un appareil de nettoyage (10) pour éliminer les SO_x , les NO_x et la suie d'un gaz d'échappement selon l'une des revendications 7-11, dans lequel l'appareil de nettoyage (10) est raccordé de manière fluide au moteur à combustion interne (12) de telle sorte que le gaz d'échappement en provenance du moteur à combustion interne peut circu-

ler à travers l'appareil de nettoyage.

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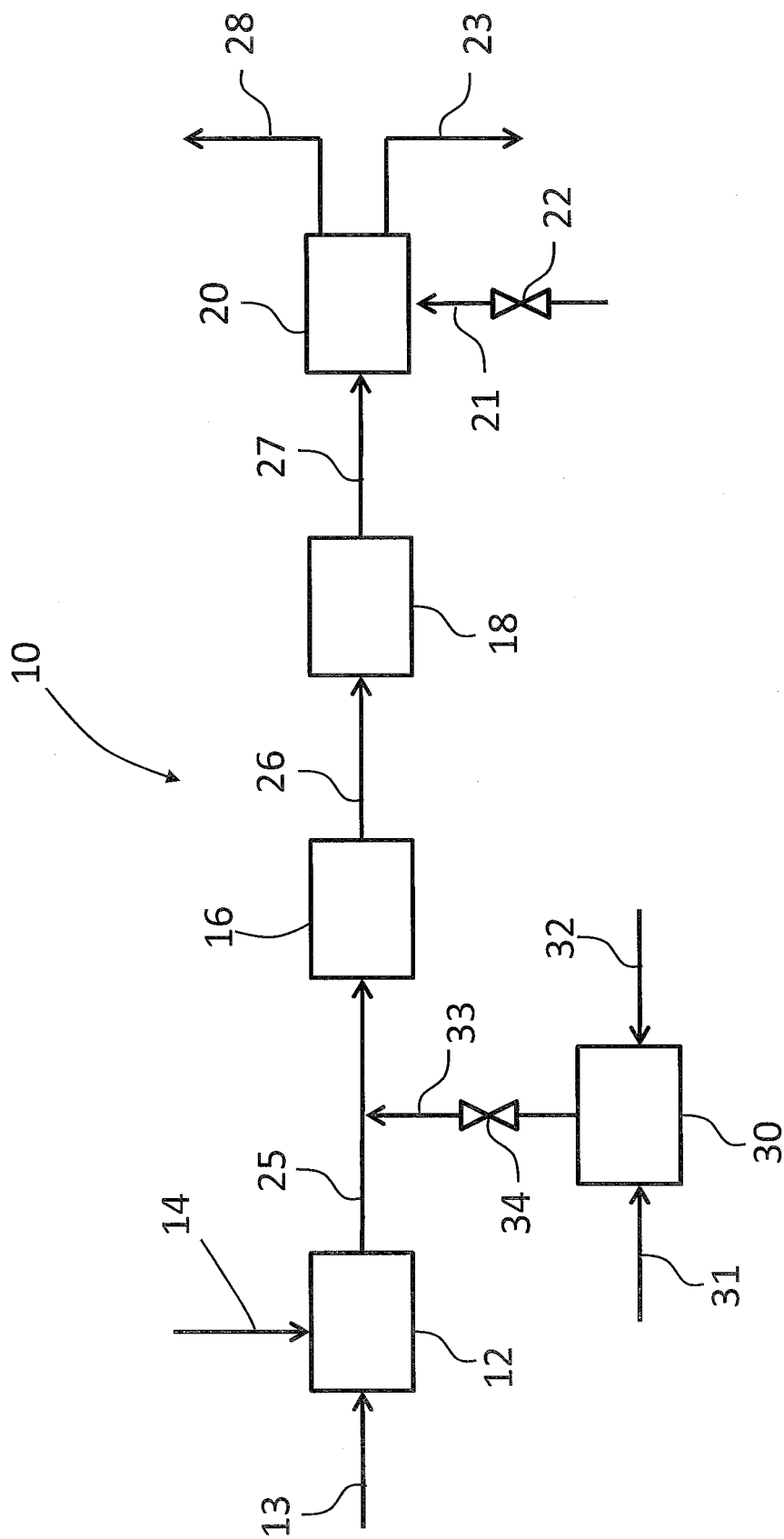


Fig. 1

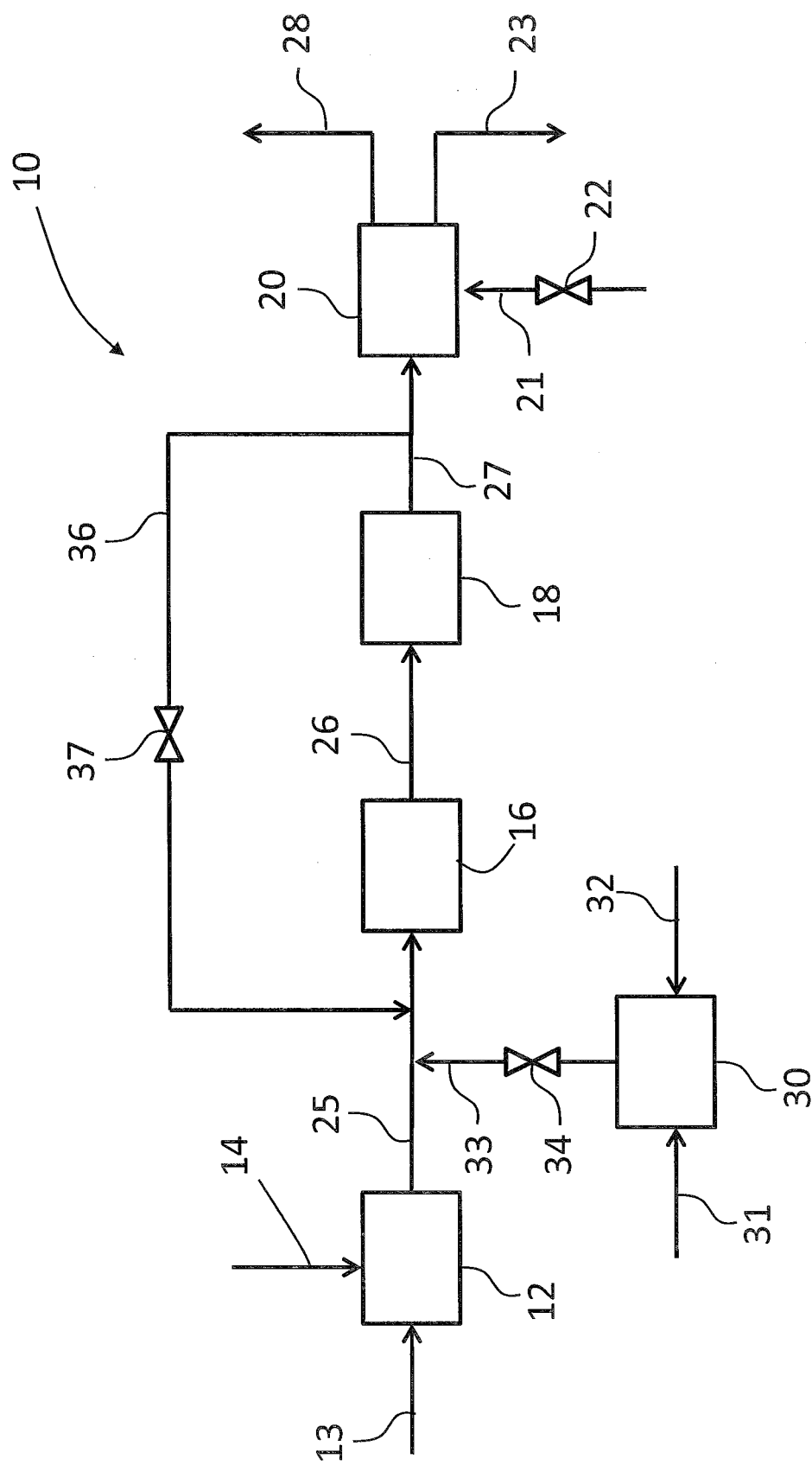


Fig. 2

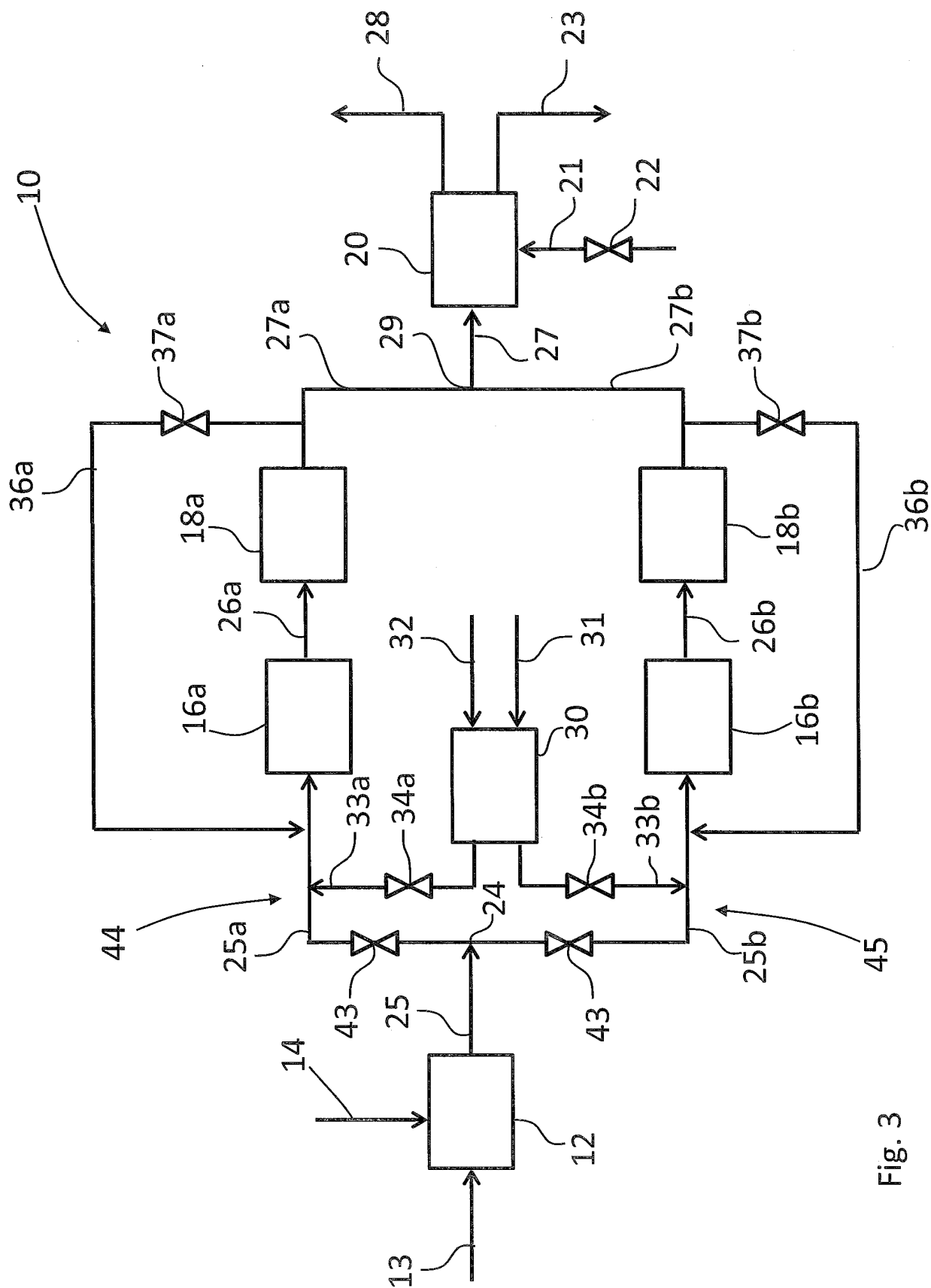


Fig. 3

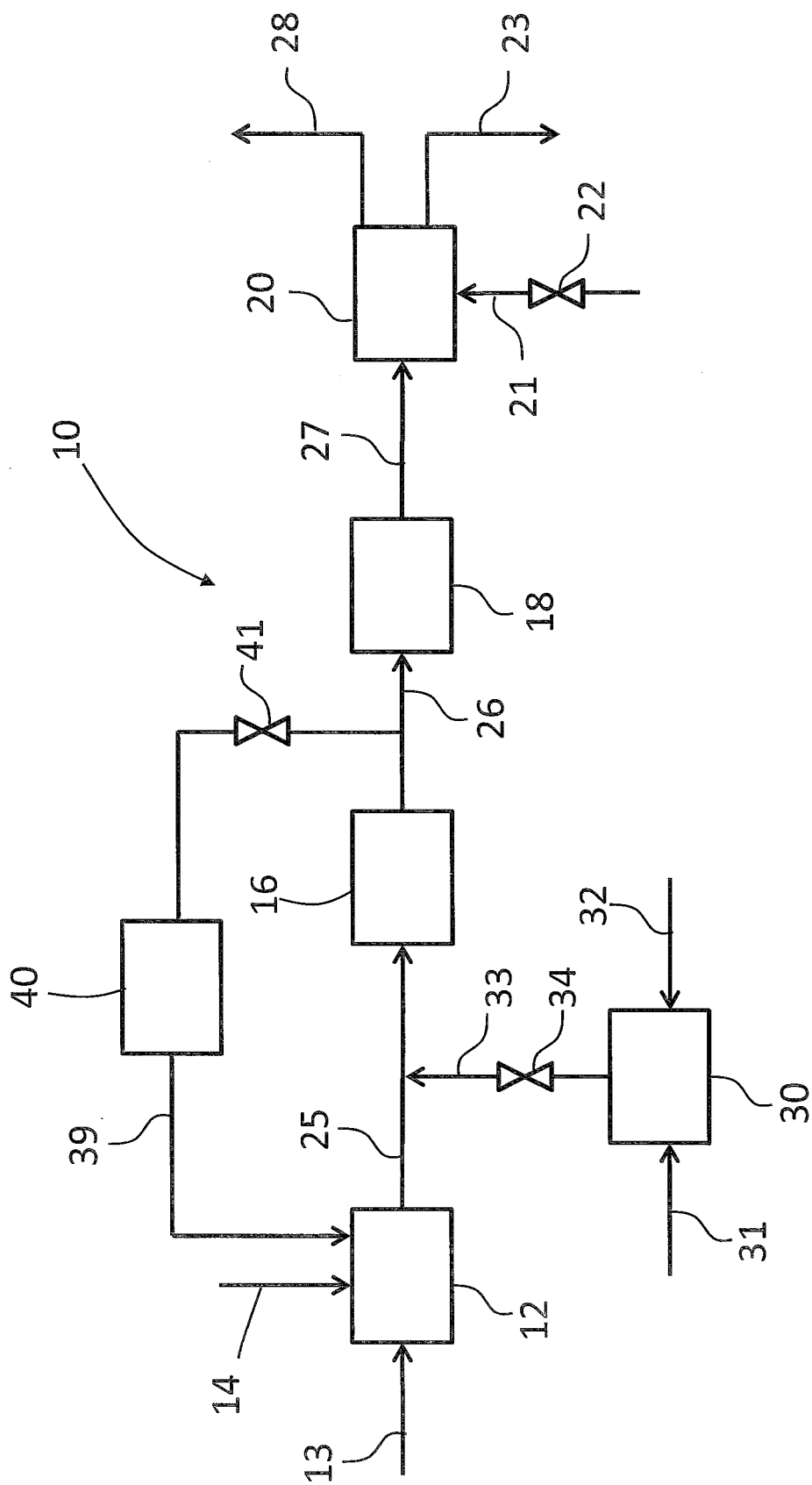


Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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